This report presents an analysis of the status of sea scallop populations in the Georges Bank, Middle Atlantic, and Gulf of Maine offshore regions of the United States. Data presented include commercial (USA and Canada) landings and effort statistics, commercial catch compositions, commercial abundance indices (catch per effort), and research vessel survey size composition and relative abundance indices. Analyses are also provided on sea scallop shell height-meat weight relationships, shell height and meat weight-ovary weight relationships, and yield per recruit. The present document is both an update and amplification of previous assessments and includes some revised data to those reported in Serchuk et al (1979). Evaluations of current resource conditions are presented and interpreted with respect to recent and historical fishing patterns and practices, recruitment prospects, and trends in population abundance levels.

Commercial Fishery

Historical Fishery (1887-1974)

Commercial landings of sea scallops from USA Northwest Atlantic waters have been recorded since 1887 (Lyles 1969; Table 1). Until the development of the Georges Bank fishery during the 1930's, commercial landings never exceeded 1,000 tons, averaging 304 tons per year from 1887-1928. During the earliest years of the USA fishery, most of the landings were harvested from the territorial waters of the State of Maine (until the 1920's) after which scallop beds off of Long Island and in the Mid-Atlantic sustained the majority of the USA catch. Between 1926 and 1935, 58% of the USA scallop landings were derived from Mid-Atlantic populations (Lyles 1969)

By 1937, Georges Bank sea scallop landings accounted for more than half of the total USA scallop catch (Premetz and Snow 1953). For the next 29 years, the Georges Bank resource was the mainstay of the domestic commercial fishery providing

77% of the total USA landings during 1944-1964. In 1965, USA scallop effort was diverted to the Middle Atlantic grounds in response to increased abundance in the southern populations due to exceptional recruitment of the 1961 year class (Posgay 1968). The offshore Canadian scallop fishery, which had developed on Georges Bank in the mid-1950's (Table 2), also displaced its activity southward during this period (Figure 2). By 1969, however, total Mid-Atlantic landings had sharply declined from the record levels of the previous four years initiating a return of the Canadian fleet to the Georges Bank fishery and the departure of many USA vessels from the scallop fishery altogether. During 1970-1974, the remaining much-contracted USA scallop fleet landed an average of only 2600 tons per year. Annual USA landings during this period were the lowest since 1945 (Table 1) with the total 5-year USA catch being only 500 tons greater than that taken in 1961 (Table 3).

The rapid development and subsidence of the Mid-Atlantic fishery in the mid-1960's and early 1970's precipitated major alterations in both the structure and conduct of the entire Northwest Atlantic offshore scallop fishery. Beginning in 1965, withdrawal of USA effort from Georges Bank (Table 4) resulted in a marked increase in the percentage of total Georges Bank landings harvested by Canada (Table 2). During 1965-1977, Canada annually accounted for greater than 70% of the total Georges Bank scallop catch, a significant departure from the proportional harvests taken from this fishery prior to 1965 (Figure 2). In addition to the large reduction in USA Georges Bank effort during 1965 to 1977 (~77% less than during 1959-1965:Table 4), the residual USA effort shifted from the traditionally productive Northern Edge and Peak region (Statistical Areas 523 and 524:Figure 3) to the South Channel area (Statistical Areas 521, 522, and 526:Figure 3). Resultingly, USA landings from the Northern Edge and Peak sharply declined, averaging

172 tons between 1965 and 1976 (Table 5), 96% less than during 1957 to 1964 and only 3.6% of the Canadian average Northern Edge and Peak landings during the same 1965-1976 time period. The effect of this change from historical USA fishing practices was that virtually all (96.5%) of the total northeastern Georges Bank scallop landings between 1965 and 1976 were Canadian. In contrast, during 1957-1964, USA Northern Edge and Peak catches comprised 53.8% of the USA Georges Bank landings (Table 6) and 54.9% of the total Northern Edge and Peak harvests.

Perhaps the most striking alteration in USA fishing activities that commenced in 1965 was the increased importance of Mid-Atlantic landings to total USA scallop yields. From 1965-1979, USA Mid-Atlantic landings were nearly twice as great (1.93x) as those from Georges Bank (Table 3); during the 15-year period, Mid-Atlantic landings exceeded those from Georges Bank in all but three years (Figure 4) and comprised 62.7% of the total USA sea scallop landings (Table 7). By comparison, Mid-Atlantic scallop catches accounted for less than 23% of USA scallop landings during 1944-1964.

A more detailed review of the historical sea scallop fishery is presented in Serchuk et al. (1979).

Recent Fishery Trends

The period from 1975-1981 has been one of great change in the scallop fishery. Total Northwest Atlantic scallop landings doubled between 1975 and 1977 (11,808 to 24,148 tons: Table 1) and reached a all-time peak of 26,672 tons in 1978 (Figure 5). Record landings were attained in the Canadian Georges Bank fishery in 1977 (13,044 tons), the USA Mid-Atlantic fishery in 1978 (8,642 tons), and the entire USA sea scallop fishery in 1978 (14,483 tons). These increased yields primarily resulted from extremely successful recruitment of the 1972 year class in almost all areas on Georges Bank and the Mid-Atlantic, coupled with marked increases in fishing effort (see COMMERCIAL EFFORT).

Total scallop landings in 1980 and 1981 (estimated projection based on January-September 1981 data) were 17,805 and 19,475 tons, respectively (Table 1). USA landings continued to decline between these years (1980: 12,566 tons; 1981: 11,475 tons) while Canadian offshore landings increased 53% (1980: 5,239 tons; 1981: 8,000 tons).

The bulk of the USA landings in 1980 and 1981 were taken from Georges Bank (44.7% in 1980; 71.9% in 1981), a departure from annual patterns observed since 1974 (Table 7). The 1981 USA Georges Bank catch (8,200 tons) was the highest in 18 years. This increase was sustained exclusively by USA Northern Edge and Peak landings which more than doubled between 1980 and 1981 (1,941 to 4,306 tons) and were the highest since 1962 (Table 5). USA 1981 landings from both the South Channel and Southeast Part regions of Georges Bank declined from 1980 resulting in Northern Edge and Peak landings accounting for 62.0% of the 1981 USA Georges Bank harvest, approximately the same proportional share of the catch as occurred in 1961-1962 (Table 6). USA Georges Bank landings during 1980 and 1981 exceeded those of Canada (1980: 5,620 vs 5,239 tons; 1981: 8,200 vs 8,000 tons) and resulted in USA landings comprising greater than 50% of the total Georges Bank sea scallop harvest for the first successive years since 1963-1964 (Table 2).

The 1981 USA Mid-Atlantic catch was only 2,100 tons, a 59% decrease from 1980, and the lowest annual yield since 1975 (Table 7). USA Gulf of Maine landings, which had averaged 253 tons per year from 1961-1979, reached 1,637 tons in 1980 (a record high) but declined to 1,100 tons (second highest ever) in 1981. In both years, approximately 70% of the Gulf of Maine landings were derived from newly discovered offshore beds in the Fishery Conservation Zone (FCZ: >3 miles from shore)(Table 8). In 1980, the Gulf of Maine offshore fishery developed in the Jeffreys Basin-Cashes Ledge region (Statistical Areas 513 and 515: Figure 3) resulting in a tenfold

increase in landings in these areas from 1979 (Table 9). In 1981, the offshore fishery shifted to FCZ populations off of Grand Manan Island and Machias Bay (Statistical Areas 511 and 512: Figure 3), virtually abandoning the scallop beds fished in the previous year (Table 9). Reliance of the Gulf of Maine fishery on offshore populations is a recent phenomenon; prior to 1950, Gulf of Maine landings were wholly from inshore, territorial waters (Baird 1956). During 1970-1978, inshore landings comprised more than 87% of the total Gulf of Maine catch (Table 8).

Distribution of Commercial Landings by Gear

Both the USA and Canadian scallop fisheries are prosecuted primarily by dredging, the traditional method of harvesting sea scallops (Smith 1891; Royce 1946; Posgay 1957; Bourne 1964). All landings from the Canadian Georges Bank fishery have been obtained using scallop dredges (Jamieson et al. 1981), while greater than 95% of USA scallop landings (1964-1980) have been taken with dredges (Table 10). On Georges Bank and in the Gulf of Maine, dredges have accounted for 98 and 99%, respectively, of USA commercial scallop landings from these regions. In the Middle Atlantic, otter trawls have occasionally accounted for a significant proportion of the annual USA Mid-Atlantic catch (e.g., 32% in 1976). When this has occurred, it has generally been a reflection of increased resource abundance conditions and hence has normally been rather short-lived. Between 1964-1980, Mid-Atlantic trawl landings of scallops comprised 8.7% of the total USA Mid-Atlantic catch (Table 10).

Distribution of Commercial Landings by Vessel Class Category

Trends in USA and Canadian Northwest Atlantic sea scallop dredge landings between 1965-1980 for each of the principal fisheries indicate major differences in the relative importance of various fleet sectors. In the Canadian fishery on Georges Bank, Class 4 vessels (151-500 gross registered tons, GRT) have always

dominated, accounting for 84.8% of the Canadian Georges Bank landings during 1965-1979 (Table 11). In the USA Georges Bank fishery, Class 3 vessels (51-150 GRT) harvested the majority of the USA landings during 1965-1978 (62.3% of the USA Georges Bank catch), but during 1979 and 1980 Class 4 vessels accounted for the greatest share of the catch (58.5%) (Table 12, Figure 6). The increased importance of Class 4 vessels in the recent USA Georges Bank fishery has resulted from the addition of newly-built larger vessels into scalloping as well as the entry of Class 4 vessels which had previously operated in other fisheries (i.e., Gulf and South Atlantic shrimp fisheries).

In the USA Mid-Atlantic fishery, Class 3 vessel landings comprised the largest proportion of the USA sea scallop harvest between 1965 and 1969 (Figure 6), accounting for 81.6% of the USA Mid-Atlantic catch. Starting in 1970, however, and continuing through all years except 1979, vessel class 4 landings have dominated the fishery. Throughout this 11-year period, 57.8% of the total USA scallop landings from the Mid-Atlantic resource were taken by Class 4 vessels. In 1979 and 1980, Class 4 vessels accounted for 42.1 and 52.1%, respectively, of the USA Mid-Atlantic catch, the lowest Class 4 annual shares since 1969. Since Class 4 Mid-Atlantic landings sequentially declined during 1978-1980 (1,381 to 1,023 tons) while Georges Bank and Gulf of Maine Class 4 vessel landings generally increased (Table 12), a displacement of Class 4 vessel activities away from the Mid-Atlantic region appears to recently have transpired.

The USA Gulf of Maine scallop fishery has always been dominated by Class 2 vessels (5-50 GRT). During 1965-1979, this smaller vessel category accounted for 90.1% of the Gulf of Maine landings. Although Class 2 landings in 1980 again predominated, vessel classes 3 and 4 accounted for significant proportions of the landings (29.3 and 30.8%, respectively: Figure 6). The development of the Gulf

of Maine offshore fishery in 1980 resulted in a 12-fold increase in Class 3 landings from 1979 and an eightfold increase in Class 4 landings (Table 12). As a result, combined landings from vessel classes 3 and 4 exceeded Class 2 landings for the first time ever. Continuation of offshore Gulf of Maine exploitation patterns in 1981 suggests that the larger vessel classes may continue to be important in the Gulf of Maine fishery in the immediate future.

Commercial Effort

Effort statistics (days fished) from the commercial scallop fisheries on Georges Bank, in the Mid-Atlantic, and the Gulf of Maine were examined for trends in both USA and Canadian annual commercial fishing patterns. USA data were derived from NMFS interview and weighout records with individual trip records aggregated, where feasible, by year and vessel tonnage category, for vessels using scallop dredges and landing in New England (1965-1980) and New Jersey ports (1978-1980) (Table 13). Total annual USA effort for Georges Bank (Area 5Ze) during 1944-1964 was taken from Caddy (1975); for 1965-1980, overall USA annual effort was determined using a derived average obtained by weighting individual USA vessel class catch rates by the yearly percentages of USA Georges Bank landings accounted for by each vessel class (Table 14). For each year, the derived catch rate was subsequently divided into the total USA Georges Bank catch to obtain total USA effort (Table 4). Canadian Georges Bank effort data were taken from Caddy (1975), from statistics provided to NMFS by Canadian scientists (J. F. Caddy and R. Chandler, personal communication), and from effort summaries listed in ICNAF and NAFO Statistical Bulletins (Tables 4 and 11).

No adjustments to any of the reported effort data have been made for possible differences in fishing power within vessel classes over time, between vessel classes, or between USA and Canadian fleet sectors.

In the Georges Bank fishery, trends in both USA and Canadian effort have tended to parallel those of landings. During 1944-1956, USA effort gradually increased from 2,220 to 12,250 days fished (5.5-fold increase) while landings nearly quintupled (4.6-fold increase) (Table 4). USA effort declined during 1957 and 1958 but stabilized at about 8,100 days per year from 1959-1964. During this same period (1957-1964), the Canadian fishery underwent rapid development; effort increased almost sixfold while landings rose over sevenfold. Between 1964 and 1965, both USA and Canadian effort sharply declined (-69% USA; -15% Canadian) as both fleets displaced their exploitation to the Mid-Atlantic grounds (Table 4, Figure 2). During the subsequent 11 years (1966-1976), USA effort remained at relatively low levels, averaging only 1,860 days fished per year, while Canadian effort steadily increased from 5,500 days (1966) to 8,400 days (1975) fished per annum. Landings in these years followed similar patterns. Beginning in 1977, USA Georges Bank effort rapidly increased, rising 2.5-fold between 1977 and 1980 (4,514 vs 11,263 days fished). Canadian effort also increased from 1976 to 1979 (7,324 to 8,823 days fished) but declined to 6,838 days in 1980 (Table 4).

Class 4 vessels (151-500 GRT) accounted for 84.1% of the total Canadian nominal effort on Georges Bank during 1965-1979, almost identical to the landings percentage attributable to this vessel class (84.8%) (Table 11). As with catch, USA tonnage class 3 vessels dominated the USA Georges Bank fishery during 1965-1978, accounting for the majority of the reported effort in each of these years (Table 13). Since 1979, however, USA Class 4 effort has exceeded that of Class 3 vessels. In 1980, effort expended by USA vessel classes 3 and 4 reached record levels for the 1965-1980 Georges Bank time series (Class 3: 4,642 days; Class 4: 6,133 days). The 1980 values for these two vessel categories increased 14.4 and 39.2%, respectively, from 1979 effort levels (Table 13).

Trends in effort in the USA Mid-Atlantic fishery since 1965 reveal three distinct periods (Table 13). The first period, from 1965-1969, was characterized by historically high effort levels, primarily by Class 3 vessels, as the Mid-Atlantic fishery underwent increased exploitation. During the second period, 1970-1974, effort stabilized at very much lower levels with Class 4 vessels accounting for the majority of effort annually. In the most recent period, effort in all vessel categories has substantially increased to the high levels observed during the first period. Class 2 and Class 3 effort peaked in 1979; Class 4 effort attained a record high in 1980. Since 1979, Class 3 vessels have again accounted for the largest number of days fished annually in the Mid-Atlantic fishery.

In the USA Gulf of Maine sea scallop fishery, virtually all effort expended during 1965 to 1980 was by Class 2 vessels (Table 13). Class 2 effort doubled between 1965 and 1970, quadrupled between 1970 and 1973, and subsequently remained at relatively high levels through 1976. Effort sharply declined in 1977 (-39% from 1976), but successively annually increased afterward, doubling between 1977 and 1980. Class 2 effort in 1980 (2,827 days) was the highest in the recent 16-year time period. Increased participation of Class 3 and 4 vessels in the fishery occurred in 1980 when offshore scallop beds in the Gulf of Maine began to be more fully exploited.

Commercial Abundance Indices (Catch Per Effort)

Annual commercial indices of catch per unit of effort (CPUE: metric tons of scallop meats landed per day fished)[2], 1965-1980, for the Georges Bank, Mid-Atlantic

[2]Reported commercial effort was in actual hours of fishing time with the dredge on the bottom, recorded to the nearest tenth of a day. Hence, CPUE values presented herein represent relative fishing performance only for the time in which dredging occurred.

and Gulf of Maine fisheries were calculated to assess relative performance of the sea scallop fleets over time (Table 14). USA data were analyzed separately, by vessel tonnage class within fishery areas, and pertain to dredge vessels landing in New England (1965-1980) and New Jersey ports (1978-1980). As previously noted (Table 10), vessels using scallop dredges accounted for greater than 95% of all USA Northwest Atlantic sea scallop landings during 1964-1981. All trips in which any quantity of scallops was landed were used in deriving annual vessel class indices. Since the dredge fishery tends to be a highly "directed" one (i.e., harvesting scallops almost exclusively), catch per effort indices should generally reflect relative fishing success for scallops. To the extent, however, that fishing power has increased through time within vessel classes (i.e., technological, procedural, and/or gear modifications), more recent annual CPUE indices may overestimate relative vessel class efficiency compared with earlier values. Appropriate catchability coefficients accounting for these factors, unfortunately, are lacking for virtually all invertebrate dredge fisheries (Caddy 1977), including scallops.

Canadian CPUE indices were derived from Caddy (1975) and from subsequent aggregate landings and effort data provided by Canadian scallop biologists. These indices basically reflect the performance of Class 4 vessels (Table 4). Additionally, annual vessel class catch rates were derived from monthly tonnage class catch and effort data listed in ICNAF and NAFO Statistical Bulletins (Table 11).

On Georges Bank, similar historical trends in commercial CPUE are evident between USA and Canadian scallop fleets (Figure 7). From 1944 to 1958, prior to the full development of the Canadian fishery, annual composite USA indices were relatively stable, varying between 0.6-0.8 tons per day. Although USA landings significantly increased throughout this time, the CPUE indices imply that fishing mortality did not measurably alter scallop abundance, a major industry concern during

this period (Premetz and Snow 1953). In 1959, both USA and Canadian CPUE values sharply increased, peaking in 1960 (USA) and 1961 (Canada), and remaining above pre-1959 values through 1963-1964 (Table 4). The elevated catch rates and correspondingly high annual landings were sustained by a marked increase in scallop abundance due to exceptional recruitment of the 1955 year class to the fishery (Posgay 1968; Caddy and Lord 1971).

During 1965 to 1972, USA and Canadian annual commercial indices steadily declined to the lowest levels in the Georges Bank fishery. By 1972, CPUE for both fleets was about 35% less than in 1965, and about one-third of the peak 1960-1961 values. Total landings in 1972, 4,967 tons, were the lowest since 1948 with USA landings (821 tons) the lowest in the recorded Georges Bank time series (Table 4). The decline in CPUE indices and the lack of appreciable recruitment during this period (Caddy 1972a, b) indicate that the intensive fishing activities of the early 1960's resulted in substantial reduction in scallop abundance on Georges Bank. The rate of decline would assuredly have been greater had not both USA and Canadian fleets directed their fishing operations to the Mid-Atlantic grounds during the mid-1960's (Figure 2).

Beginning in 1973, yearly CPUE values sequentially increased, culminating in 1977 in a record CPUE for the Canadian fleet (1.52 tons/day fished) and a near-record CPUE for the USA fleet (1.06 tons/day fished) (Figure 7). Total annual landings tripled during this interval (5,288 to 17,849 tons: Table 4), primarily due to high levels of Canadian effort and the recruitment of the outstanding 1972 year class into the commercial fishery (MacKenzie et al. 1978; Serchuk et al. 1979). Subsequently, however, commercial CPUE on Georges Bank has dropped sharply; both USA and Canadian 1980 indices were half of the 1977 values, with the 1980 USA CPUE being the third lowest in the 37-year period since 1944. Although total landings

peaked in 1977, effort continued to increase resulting in record highs in 1979 (Canada) and 1980 (USA and Total) (Table 4). These trends imply that recent levels of fishing mortality on Georges Bank have been extremely high.

Estimated total Georges Bank landings in 1981 were 16,200 tons (USA: 8,200 tons; Canada: 8,000 tons),about a 50% increase from 1980 (Table 2). Preliminary USA CPUE data for the first seven months of 1981 show a marked increase in catch rates for all vessel classes fishing on the Northern Edge and Peak (about 62% of the 1981 USA Georges Bank landings was caught in this region); monthly CPUE values in late spring and early summer 1981 were extremely high ranging between 0.9 and 2.0 tons/day fished. Research survey and commercial size-frequency data indicate that the 1981 Northern Edge and Peak fishery relied heavily upon very successful recruitment of the 1977 year class in this area of Georges Bank (see COMMERCIAL CATCH COMPOSITION and RESEARCH SURVEY RELATIVE ABUNDANCE INDICES).

Yearly trends in both USA and Canadian individual vessel class CPUE indices during 1965-1980 are concordant with the patterns derived from the aggregated Georges Bank analyses (Tables 11 and 14, Figure 8).

In the Mid-Atlantic sea scallop fishery, USA commercial CPUE indices for vessel classes 3 and 4 during 1965-1980 exhibited similar chronological directionality as those for Georges Bank (Table 14, Figure 8). Annual values steadily declined from 1965-1971 (over a 60% reduction in both classes), stabilized briefly at low levels in 1972-1973, and then rapidly increased through 1977. The 1977 catch rates (Class 3: 1.14 tons/day fished; Class 4: 1.32 tons/day fished) were the highest ever in the fishery, eclipsing the previously high 1965 values by 14 and 20%, respectively, and were more than threefold greater than historically low indices observed in 1971. As on Georges Bank, these prominent 1977 CPUE levels resulted from recruitment of the extremely abundant 1972 year class throughout the Mid-

Atlantic fishery region (Serchuk et al 1979). Since 1977, annual USA CPUE indices have steeply declined. In 1980, both USA Class 3 and 4 catch rates were over 60% lower than in 1977, and among the lowest CPUE values in the 1965-1980 time period. Despite the decline in CPUE, total USA effort in the Mid-Atlantic fishery sharply increased during 1978-1980 resulting in a record high in 1980 (Table 13). Applying the 1980 USA annual mean catch rate (0.45 tons/day fished) for New England and New Jersey scallop dredge vessels landing scallops from the Mid-Atlantic resource (Table 14) to the 1980 total USA Mid-Atlantic catch (5,090 tons: Table 3) results in an estimated 1980 Mid-Atlantic effort of greater than 11,300 days fished.

The apparent decline in Mid-Atlantic scallop abundance implied by the recent reductions in commercial catch rates has been roughly compensated in terms of gross harvest revenue by substantial increases in ex-vessel prices (Table 15). The 1980 USA average landed price per pound of scallops ($3.84) was 2.4 times higher than in 1977 ($1.62) whereas the 1977 mean Mid-Atlantic CPUE (1.24 tons/day fished) was 2.8-fold greater than in 1980 (0.45 tons/day fished) (Table 14). Accordingly, through 1980, there remained an economic incentive to continue exploitation of the Mid-Atlantic sea scallop resource (as well as Georges Bank) despite the sizable decreases in population abundance.

Preliminary data for 1981 (January-June) indicate that USA Mid-Atlantic catch rates have declined further. Projected 1981 Mid-Atlantic landings (2,100 tons: Table 3) were the lowest since 1974 when CPUE was almost double the 1980 mean value. Average ex-vessel price of scallops in 1981 (based on preliminary New Bedford data) was only 3 cents higher than in 1980. These factors suggest that resource abundance further deteriorated in the Mid-Atlantic during 1981 and that the economic stimulus for concentration of fishing effort in this region has greatly diminished. The

appearance of many Mid-Atlantic based scallop vessels on Georges Bank during 1981, and the concomitant increased emphasis by the New England scallop fleet in 1981 in fishing the Georges Bank grounds tend to corroborate these inferences.

In the USA Gulf of Maine inshore scallop fishery, Class 2 vessel annual catch per effort indices (Table 14, Figure 8) best reflect trends in commercial fishing performance since greater than 90% of the 1965-1979 landings was taken by this class of vessels. Class 2 CPUE values gradually declined by over 60% between 1965 and 1974 (0.38 vs 0.14 tons/day, respectively). Class 2 landings almost quintupled between 1965 and 1972 while effort increased ninefold (Tables 12 and 13). Apart from 1975 when Class 2 CPUE rose sharply, recent annual catch rates have remained at relatively low levels.

Class 3 and 4 catch indices are most relevant in indicating the development of the offshore Gulf of Maine fishery which commenced during the winter of 1979-1980. The 1980 CPUE indices for these vessel classes (Class 3: 1.24 tons/day fished; Class 4: 1.82 tons/day fished) were the highest on record, and surpassed even the highest Class 3 and 4 annual catch rates recorded in both the USA Georges Bank and Mid-Atlantic fisheries during 1965-1980 (Table 14). The initial development of the fishery, principally in the Jeffreys Basin-Cashes Ledge area in 1979-1980, resulted in a tenfold increase in landings and about a fivefold increase in effort by Class 3 and 4 vessels between 1979 and 1980 (Tables 12 and 13). However, the abrupt withdrawal of fishing activity from this region in 1981 (Table 9: compare landings in 1980 and 1981 for Statistical Areas 513 and 515) to more northeasterly offshore areas in the Gulf of Maine (i.e., Grand Manan offshore waters) connotes that the 1980 catch rates were not sustainable; the rapid decline in Jeffreys Basin-Cashes Ledge landings in 1981 implies that fishing pressure, supported primarily by recruitment from the 1975 year class of scallops (see COMMERCIAL CATCH COMPOSITION), may have materially reduced resource abundance in this region.

Commercial Catch Composition

USA size frequency sampling of commercial sea scallop landings has been conducted since the 1950's (Posgay 1962). Since 1965, the sampling protocol has been to measure shell height (greatest distance between the umbo and ventral shell margin) from a random sample of shells (top valve only) obtained during the last tow of a vessel trip. Measurements are recorded by 5 mm intervals. Prior to 1972, scallops larger than 149 mm shell height measured in the USA commercial samples were grouped in the 145-149 mm size frequency interval, effectively truncating the upper end of the frequency distributions in these years. Since 1972, the actual size interval of these larger sized individuals has been recorded. In all years, the statistical area from which each sample was obtained and the gear used have been routinely chronicled. Additional data on depth fished, trip catch, vessel identification, and date of sample collection have also been collected.

Samples from vessels using scallop dredges account for virtually all of the USA size frequency data obtained during 1965-1981, reflecting the almost exclusive reliance in the USA fishery on dredging to capture scallops (Table 10). Accordingly, no evaluation of commercial catch composition in other than the dredge fishery has been performed.

For all years, annual shell height distributions were derived for each principal sea scallop fishing region on Georges Bank (South Channel, Southeast Part, and Northern Edge and Peak) and in the Middle Atlantic (New York Bight, Delmarva, and Virginia-North Carolina) (Figure 3). Gulf of Maine size frequencies were also derived for all years in which samples were available. Within each region, yearly size composition was determined by aggregating all samples collected within each year. From the resultant annual size frequency array, the percentage dis-

tribution of sampled scallops, at 5 mm shell height intervals, was calculated. Mean shell height, mean meat weight per scallop, and average meat count (i.e., number of scallop meats per pound) were subsequently derived from the annual frequency distributions. Mean meat weight per scallop was determined through application of area-specific (Georges Bank, Mid-Atlantic, and Gulf of Maine) shell height-meat weight equations to the shell height frequencies represented in the frequency distributions (see SHELL HEIGHT-MEAT WEIGHT RELATIONSHIPS); the average meat count was obtained by dividing the calculated mean meat weight per scallop into 453.6 grams (i.e., one pound).

To assess within-year size variability of the commercial samples from each fishing region, meat counts were individually determined for all samples and annual frequency distributions of the sample meat counts (in 5 unit intervals) were tabulated.

Composite annual size frequency distributions of scallop samples from both the Georges Bank and Mid-Atlantic fisheries were derived by weighting the yearly shell height distributions from each of the three principal scallop regions in both fisheries by the respective annual USA scallop landings from these regions. In effect, these composite distributions reflect the estimated size composition of the USA landings in each year.

Annual shell height frequencies for 1965-1980 from USA Georges Bank samples are depicted in Figures 9-12. Summary statistics on sample sizes, mean shell height, mean meat weight, and average meat count are presented, by principal scallop fishing region and year, in Tables 16 (1965-1974) and 17 (1975-1981).

The frequency distributions indicate that scallops on Georges Bank become recruited to the USA fishery after attaining a size of 70 mm shell height, the 50 percent selection point of commercial scallop dredges equipped with 3-inch

(76 mm) rings (Posgay 1962). Size selection of scallops by commercial dredges, however, is not sharp due to the accumulation of trash and scallops in the gear during towing (Bourne 1965, 1966). Equally, dredge efficiency progressively decreases with size for scallops below 100 mm shell height due to the ability of these smaller-sized individuals to elude capture by swimming away from the dredge path (Caddy 1968). Accordingly, the smallest sizes of scallops appearing in the landings generally reflect prevailing culling practices since commercial catches are normally sorted on deck before shucking, and undersized scallops returned overboard. Historically, the 50% cull size in the USA Georges Bank fishery has varied between 85-110 mm shell height (Posgay 1962, 1979; Brown et al. 1972), with reductions in cull size generally transpiring during years of good recruitment.

During 1965-1980, the average size of scallops in any of the USA Georges Bank annual frequency distributions ranged between 98.6 mm (South Channel, 1977) and 133.5 mm (Southeast Part, 1965) (Tables 16 and 17). Among principal fishery regions on the Bank, the mean size of scallops from the Southeast Part has consistently been larger than those from the South Channel or the Northern Edge and Peak. In none of the regions, however, did annual USA average meat counts exceed 28 per pound until 1981 when the mean size of South Channel and Northern Edge and Peak scallops were the smallest in the recent sampling time series (92.8 and 86.7 mm shell height, respectively).

Prior to 1981, only two USA samples of the 750 collected from Georges Bank between 1965 and 1980 had individual meat counts greater than 40 per pound (Tables 18 and 19). Most samples collected during 1965-1971 were less than 20 count (Table 18) while the majority of individual samples from 1972-1980 were less than 25 count (Table 19). These data, in conjunction with the growth rate of sea scallops on Georges Bank (Table 20), imply that the average age of landed scallops in the USA fishery has (until 1981) rarely ever been less than 4 years of age.

The composite USA Georges Bank shell height frequency distributions for 1966, 1970, and 1976 and 1977 display prominent modes at about 90 mm (Figure 9). Examination of the corresponding annual size distributions from each of the three fishery regions on the Bank (Figures 10-12) indicates that during 1966 and 1970 these modes were represented by South Channel landings almost exclusively, while during 1976 and 1977, these peaks were evident in all fishing areas. The increased proportion of smaller-sized scallops in the USA samples during these years suggests that incoming recruitment was relatively stronger than in adjacent periods. This is further reflected in the declines in average shell height and meat weight that occurred during these four years (Tables 16 and 17) and the increases in the percentage of samples containing elevated meat counts (Tables 18 and 19). The observed uptrends in USA Georges Bank CPUE in these years (particularly Class 3 indices) additionally imply that heightened year class recruitment transpired in the USA fishery during these times (Table 14). Finally, the subsequent progression and integrity of the height frequency modes in succeeding annual frequency distributions denotes that this recruitment was real and not a sampling artifact. Research vessel survey results from 1975 onward indicate that the commercial size frequency modes in 1976 and 1977 reflect the entry of the outstanding 1972 year class in the Georges Bank fishery (MacKenzie et al. 1978; Serchuk et al. 1979). The recruitment that occurred in 1966 and 1970 in the South Channel was probably more localized and of a lesser magnitude than either that of the 1972 year class or the exceptional 1955 year class. Nonetheless, this recruitment was sufficient to initiate reductions in the average age at harvest from 5 to 4 years for the USA fleet (Brown et al. 1972) and from 5 to 3 years of age for scallops landed in the Canadian Georges Bank fishery (Caddy 1971).

As noted previously, the mean size of scallops sampled from the 1981 USA Georges Bank landings was the smallest in the 1965-1981 period (Tables 16 and 17). Individual meat counts exceeded 60 count in 22% of the USA samples obtained from Northern Edge and Peak landings during January-September 1981 (Table 19). Elevated meat counts were equally characteristic of samples from South Channel landings. Provisional size frequency distributions from the 1981 sampling exhibit a prominent mode between 70-84 mm shell height indicating that scallops from the 1977 year class predominated the landings; a similar pattern prevailed in samples obtained from the 1981 Canadian Georges Bank fishery (G. Robert, personal communication). This dominance of the 1977 year class in the 1981 USA and Canadian commercial landings is concordant with 1980 and 1981 research vessel abundance indices which indicated that the 1977 year class was the principal year class in the Georges Bank resource and was stronger than the outstanding 1972 year class (see RESEARCH SURVEY RELATIVE ABUNDANCE INDICES), albeit more localized in distribution.

In the USA Mid-Atlantic fishery, annual shell height frequency distributions during 1965-1980 indicate a similar size at recruitment for scallops to the dredge fishery as on Georges Bank (Figures 13-16). Scallops less than 70 mm shell height have rarely occurred in Mid-Atlantic commercial samples implying virtually identical culling policies as for the Georges Bank fishery.

The average size of scallops in the Mid-Atlantic annual frequency distribution has varied between 95.4 mm (1965: Delmarva) and 122.5 mm shell height (1978: Delmarva) (Tables 21 and 22). Little consistent differences are evident in either the mean size or size range of scallops sampled from any of the Mid-Atlantic areas. During 1965-1971, sample meat counts seldom exceeded 40 count, with most samples less than 25-30 count (Table 23). Generally higher sample meat counts occurred during 1965-1967 when the Mid-Atlantic fishery was sustained by unprecedented recruitment from the 1961 year class (Posgay 1968).

The weighted aggregated Mid-Atlantic shell height frequency distributions for 1965, 1966, 1972, 1974, and 1976 all indicate reliance in the USA fishery on incoming recruitment (Figure 13). Recruitment of the extremely abundant 1961 year prevailed in each of the three Mid-Atlantic scallop regions during 1965-1966 (Figures 14-16). Recruitment during 1972 was much more localized, occurring principally in the Delmarva region (Figure 15). The slight increase in USA Mid-Atlantic CPUE during 1972 (Table 14) reflects this recruitment since most of the 1972 Mid-Atlantic landings were obtained from Delmarva (Table 3: Area 6B); greater than 50% of the 1972 Delmarva samples had meat counts higher than 30 per pound (Table 24). In 1974, localized recruitment again occurred but this time in the New York Bight area, where the size frequency distribution indicated a distinctive mode between 82-97 mm shell height (Figure 14). Mid-Atlantic scallop growth rate data (Table 20) imply that this mode corresponds to the size expected for age 4 scallops, i.e., the 1970 year class. Average shell height in New York Bight samples significantly declined in 1974 (98 mm vs 111 mm in 1973) and sample meat counts increased (Tables 21 and 24). The entry of the 1970 year class into the Mid-Atlantic fishery was accompanied by a substantial increase in USA commercial catch per effort in 1974 (Table 14) and an increased reliance on the New York Bight area in sustaining USA Mid-Atlantic scallop landings (Table 3). Recruitment in 1976 was widespread in the Mid-Atlantic; a prominent shell height mode between 87-97 mm appeared in both New York Bight and Delmarva annual frequency distributions (Figures 14 and 15) indicative of entry of the strong 1972 year class into the fishery. This year class, the strongest to appear since the 1961 cohort, dominated the fishery through 1980 as evidenced by the increase in landings throughout this period and the successive modal progression of the 1972 year class in the Mid-

Atlantic size frequency distributions from 1976 to 1980 (Figure 13). Size frequency distributions from the Delmarva and Virginia-North Carolina regions in 1979 and 1980 (Figures 15 and 16) indicate that some additional localized recruitment occurred from both the 1975 and 1976 year classes as well.

Provisional 1981 size frequency sample data from the Mid-Atlantic region indicate a continued dependence on larger-sized scallops (>110 mm shell height) in the USA commercial fishery. Average 1981 meat counts in all three fishery areas in the Mid-Atlantic were less than 15 count, among the lowest in the 1965-1981 sampling time sequence (Tables 21 and 22). Recruitment of the 1977 year class appears to be relatively minor in all Mid-Atlantic areas; only one of the 16 size frequency samples obtained from Mid-Atlantic landings during January-September 1981 had a meat count higher than 30 (New York Bight: Table 24).

Commercial sampling of USA Gulf of Maine scallop landings has been less encompassing than in either the Georges Bank or Mid-Atlantic fisheries (Table 25). Aside from 1980 when a special effort was made to obtain samples from the developing offshore fishery, the number of samples collected annually has been relatively low. To a large degree, this has been a reflection of the minor proportion of total USA scallop landings originating from the Gulf of Maine; only 3.5% of the total USA scallop catch during 1961-1979 was derived from the Gulf of Maine (Table 7).

The limited sampling data indicate that prior to 1972 most of the Gulf of Maine landings were comprised of scallops larger than 110 mm shell height (Figure 17), with individual sample meat counts never more than 25 count (Table 26). During 1972-1974, average annual meat counts increased to 27-30 count (Table 25), as incoming recruiting year classes dominated the size frequency distributions

(Figure 17). This situation abated in 1975 but reappeared during 1977-1980. In 1978 and 1980, virtually no scallops larger than 120 mm shell height were present in the size frequency samples, in striking contrast with previous years. Cull size in the 1980 offshore fishery was also lower than in preceding periods with sample meat counts as high as 80-85 count being observed (Table 26). In part, this resulted from increased shell stocking operations in 1980 and entry of Mid-Atlantic-based vessels into the Gulf of Maine fishery. In response to these circumstances, the States of Maine and Massachusetts prohibited the landing of sea scallops less than 3 inches (76 mm) in shell height at their ports.

The modal height of about 90 mm in the 1980 size frequency distributions (Figure 17) suggests that the offshore fishery was sustained primarily by recruitment from the 1975 year class (Table 20). This supposition is based on growth rate patterns of inshore Gulf of Maine scallops but, due to similarities between offshore and inshore height-weight equations (see SEA SCALLOP SHELL HEIGHT-MEAT WEIGHT RELATIONSHIPS) appears generally applicable to the offshore populations.

Provisional 1981 Gulf of Maine size frequency sampling data indicate a substantial decrease in sample meat counts from 1980 although this observation is derived from only three samples obtained during January-September 1981 (Tables 25 and 26).

Recreational Fishery

A limited recreational fishery for sea scallops exists in shallow, inshore waters north of Cape Cod in which scallops are retrieved by scuba diving. Most of this activity occurs in estuaries and embayments in the territorial waters of the State of Maine at depths less than 15 fathoms. Detailed landings data do not exist for the recreational fishery but it is probable that total annual recreational cathces are considerably less than a metric ton of meats. The State of Maine limits the recreational catch of sea scallops to one gallon of shucked meats per person per day during the sea scallop season, November 1 through April 15.